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ABSTRACT

Problem-based learning (PBL) was used as the instructional design basis for a TAFE (Technical and Further Education) unit of competency developed for online delivery. The courseware was commissioned to provide online content for users of the Victorian TAFE Virtual Campus (Australia). The aim of the project was to provide courseware that would develop competency in the horticulture course topic "Soil Characteristics and Survey Techniques" and also develop generic skills in communication and collaboration. This paper provides a theoretical basis for the application of PBL to instructional design and a case study of the development, trial application at the University of Melbourne (Australia), and evaluation of the project. (Contains 13 references.) (Author/MES)

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TEACHING SOILS ONLINE USING A PROBLEM-BASED LEARNING DESIGN

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Abstract

Problem-based learning (PBL) was used as the instructional design basis for a TAFE unit of competency developed for online delivery. The courseware was commissioned to provide online content for users of the Victorian TAFE Virtual Campus. The aim of the project was to provide courseware that would develop competency in the course topic 'Soil Characteristics and Survey Techniques' and also develop generic skills in communication and collaboration. This article provides a theoretical basis for the application of PBL to instructional design, and a case study of the development and a trial application of the project.

Keywords

cognition, constructivism, problem-based learning, authentic assessment, multimedia, online learning, instructional design, evaluation, generic skills

Introduction

One of the most important reasons for using online technologies in education is to support flexible modes of learning that suit the diversity of learner needs and enable learners to develop a wide range of skills. These skills include technological literacy and the capacity for self-directed learning, as prerequisites for lifelong learning in a rapidly changing society. Development of these skills is an important part of the rationale for the Victorian TAFE Virtual Campus (TAFEVC). To foster the development of these skills, teachers using the TAFEVC are encouraged to develop courseware that 'provides active, meaningful learning experiences for individuals and opportunities to communicate and collaborate with others' and to 'ensure that online programs form a holistic option for learning by implementing techniques for validation of assessment processes and practical exercises' (PETE, 2001, p. 11). To support this development, TAFE in Victoria have sponsored the development of online content in a wide variety of subject areas. The online content materials can be used by teachers to support student learning of complete units of competency, for on-campus or external students. They are freely available to all Victorian TAFE providers using the TAFEVC.

This paper considers the design and development of an online unit of competency in Horticulture, covering soil sampling and survey techniques. A problem-based learning (PBL) approach was used as this particular approach to teaching and learning has been developed to build generic skill capacity through active learning methods that ask the student to deal with real problems from practice (Candy, Crebert & O'Leary, 1994). The case study focuses on the design and development of the course using the PBL approach, with evaluation data from a small student group who were the first to use the unit. The students used the unit in an external study mode.

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Needs for Online Courseware

The introduction of online learning materials is seen to have significant long-term implications. In a forward planning document for the introduction of the TAFEVC, the State Training Board of Victoria (STBV) identified three key outcomes that should be achieved through effective development and use. These are:

- improved learning outcomes through creative applications of technology in teaching/learning transactions;
- greater access to and participation in training through more flexible approaches to mainstream delivery; and
- familiarisation with and practice in the applications of information technology required in vocational settings.

Online technologies are seen to have the potential to create new approaches to teaching and learning, while 'also enhancing traditional delivery models' (STBV, 1998, p. 3). An important part of the rationale for the application of online technologies is the deregulation of the marketplace for training, leading to a national and international market for training courses.

In a later document the same goals were outlined, and additional goals relating to a capacity for self-directed learning leading to the ability for lifelong learning were stressed. To achieve this, enabling strategies were recommended, including strategies that would:

- encourage the development of courseware that provides active, meaningful learning experiences for individuals and opportunities to communicate and collaborate with others; and
- ensure that online programs form a holistic option for learning by implementing techniques for validation of assessment processes and practical exercises (PETE, 2001, p. 11).

The attainment of these goals requires new approaches to providing learning materials using online technologies.

Rationale and Characteristics of Problem-based Learning

PBL was selected as the preferred basis for the instructional design of the project materials as it is an approach to learning that is designed to develop learning for capability rather than for the sake of acquiring knowledge (Engel, 1997). The PBL approach is based on constructivist principles in which the emphasis is placed on the learner's actions in reaching an understanding of the topic. As the learner must actively try to solve the problem, no passive learning for an essentially reproductive task is viable for the learner. Some important attributes of the constructivist approach as it relates to PBL are:

- understanding is developed through our interactions with the environment;
- the stimulus for learning is a cognitive conflict or problem, and this determines the organisation and nature of what is learned; and
- knowledge evolves through social negotiation and through evaluation of the viability of individual understandings (Savery & Duffy, 1994).

These attributes are applied in a PBL framework as the learner is first presented with the problem that needs to be solved. This is followed by a guided learning process in which the learner, either alone or in a collaborative process with other students and the tutor, clarifies the problem and acts to acquire the necessary knowledge and skill to reach a satisfactory resolution (de Grave, Boshuizen & Schmidt, 1996). The learning process is motivated by the learning task, and the environment for the problem becomes the environment that the learner interacts with in problem-solving. This provides a challenging environment in which the students learn to use information in meaningful ways (Margetson, 1997).

A desirable attribute of problems used in PBL is that they should be 'ill-structured' (Koschmann,

Kelson, Feltovich & Barrows, 1996). Many academic tasks require well-structured problem-solving, in which the student works towards a convergent or single known solution. Many of the situations that students will experience when they graduate however, are complex and are open to several different solutions. Dealing with problems of this nature may require different skills from problems that have a single solution (Jonassen, 1997). Problems are ill-structured or ill-defined if the problem statement does not readily specify the solution so that the learner must learn to identify the real nature of the problem, any information that is necessary but missing from the problem statement, and a process for arriving at a solution (Jonassen, 1997).

The principal reason for using a PBL approach is to develop generic skills that are of value across the curriculum and, more importantly, in the students' professional environments following graduation, or during the course of study for part time students. Some of the generic skills that are developed in the PBL approach are:

- adaptability to change;
- dealing with complex problems and making reasoned decisions in unfamiliar situations;
- reasoning critically and creatively;
- adopting a holistic approach to problem situations;
- practicing empathy and appreciating the other person's point of view;
- collaborating productively in groups or teams; and
- identifying your own strengths and weaknesses, and achieving some remediation for weaknesses through self-directed learning (Engel, 1997)

An important part of the skill of the instructor who is using a PBL approach is to select problems that will enable and encourage the students to develop the above skills in the learning environment that is created. Learning tasks need to be authentic by representing or being based on real problems that the students may have to confront. The student is placed in the situation of being or playing the role of a stakeholder in the problem situation, such as being a consultant who is requested to find a solution or course of action for dealing with the problem (Sage & Torp, 1997). Assessment must be based on the skills required in problem-solving by assessing the performance of the skills in a realistic situation (Reeves & Okey, 1996). The application of assessment to the resolution of the problem tasks forms a basis for what Biggs (1999) describes as 'alignment'. He considers that PBL is a perfect example of alignment as the: "objectives are to get the students to solve problems they will meet in their professional careers—the teaching method is to present them with problems to solve; the assessment is based on how well they solve them." (Biggs, 1999, p. 71).

PBL is a powerful approach to teaching and learning as it focuses student learning towards the type of situation they will be working in as a graduate, and builds confidence in being able to function in these roles. By using this approach to design instructional multimedia materials, the power of PBL can be applied, and enhanced, using instructional technologies.

Case Study – A Course in Soil Sampling and Survey Techniques

The Institute of land and Food Resources at the University of Melbourne received funding to develop an online course for the unit of competency taken from the Horticulture Training Package - RUH HRT 358A Survey Soil Characteristics. The competency-based nature of the topic is suited to a PBL approach. The first two columns in Table 1 are an extract from the Horticulture Training Package and detail the industry competency specifications and performance criteria. These specifications were the starting point for the course design. When using PBL one of the most critical issues is the selection and specification of the problems. These need to represent real-world applications that require all of the necessary knowledge and skill to resolve (Stinson & Milter, 1996). A series of problems on soil sampling and soil analysis that matched the required competencies and performance criteria were needed.

Element of Competency	Performance Criteria	Instructional approach
358.1 Determine soil characteristics by performing a soil survey		The problem scenario is based on a couple who plan to set up a commercial flower growing enterprise. We are introduced to them and they explain what they aim to achieve, the type of plants they wish to grow, and how they need to prepare their land. They begin with the process of sampling the soil to determine its suitability for a range of plants.
	358.1.1 The density and depth for a representative sampling of the area are determined in consultation with the supervisor.	By using the resource material, students need to locate all information on the proposed growing site necessary to complete the paddock information form. The student is asked to identify where on the property the sampling should take place, and the sample depth etc. given photographs and a sketch map of the property. The student is advised of the resources that are available to help with the task. These include: • A virtual version of the sample bag used to send the samples to the lab; • Sampling instructions from the laboratory; • An expert who can be 'asked' for advice (photos, audio) from the lab; and • An online tutorial on sampling techniques.
	358.1.2 Holes are excavated as determined at sampling sites according to enterprise policy.	
	358.1.3 Soil samples are collected for off-site assessment using recommended procedures.	Students are to complete a paddock information form and the label for the couple, and submit this for assessment. Students demonstrate actual sampling to a teacher or workplace supervisor.

Table 1: A sample of the competency statement (Columns 1 and 2) and the teaching/learning strategy

The initial design issue was to select the range of problems. These needed to be real tasks that would require the students to learn and apply the skills specified in the competency statement. It was also important for the problem tasks to be the assessable tasks. The aim was to ensure a motivational context for the students by making the problem tasks realistic and assessable, and to structure the problems to bring the objectives, instructional methods and assessment into alignment in accordance with Biggs' (1999) recommendations. The problems selected were based on:

a) a real scenario of two growers in the process of establishing an flower-growing operation; and
b) the students' own properties or workplaces.

The problem tasks are either to propose a solution to a specific issue for the two growers, or for the students to use the growers' situation as a trigger but to carry out the task on their own property or workplace.

The analytical process is illustrated in Table 1. Five problem tasks were selected to cover the entire course. Column 3 shows the description of the first problem task, to illustrate how attainment of the performance criteria would be embedded in the problem-based instruction. The complete analytical document detailed the same process for the entire course, covering two elements of competency and all associated performance criteria.

Figure 1: Main Menu showing the range of problems

A reference group was an important part of the analysis and design process. This group consisted of a range of representatives from local industry, government organisations and other colleges. This group was invited to consider the project at several stages of development beginning, critically, with the initial analysis document illustrated in Table 1. Many suggestions came from this group that made the design more accessible (such as including a text version as an optional alternative to audiovisual presentations), and helped to clarify issues relating to the interpretation of the performance criteria. This group was involved at milestone stages in the development of the project.

The course materials are structured to include all course content in the resource materials associated with one of the five problems. The menu structure for these is illustrated in Figure 1. (One additional scenario is not visible in the screen shot). Each problem is presented as realistically as possible using an audiovisual presentation of the scenario in many cases (see Figure 2). Grouped with each problem are the resources the student may use to carry out the learning task. These consist of illustrated content material and links to other websites such as Victorian Resources Online.

Students are provided with content materials in the form of a resource collection that enables them to explore the content. The menu structure facilitates exploration by providing a standard navigation link back to the resource page so that students can move rapidly from one resource area to another. The problem-based structure encourages the students to be searching for meaningful solutions as they are immersed in the task while they are using the resource collection. The content materials are presented in some depth as the students need a comprehensive knowledge of the subject area.

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Figure 2: Audiovisual presentation of a problem scenario

Within the course there is a high level of emphasis on practical applications. Students carry out tasks such as making a physical and chemical analysis of the soil on their own property or workplace. To ensure that the practical competence is attained, a sign-off sheet listing a range of practical tasks, can be downloaded from the courseware. These need to be demonstrated to a teacher or workplace supervisor. In this way, students working at a distance from the campus can complete all aspects of the course. Assessments can be submitted electronically. These need to be accompanied by the hard copy version of the sign-off sheet indicating attainment of the practical skills.

An important part of each learning task is the online discussion. Students are advised that they need to use this while they are working on each of the learning tasks. Discussion topics are included in the specifications of the task. The teacher, however, may add more of these as necessary, as can the students. As each problem task will take 2-3 weeks to complete the teacher will have plenty of scope to add additional topics. The online discussion can be used by the teacher to facilitate sharing of information among the students, and to encourage sharing of ideas through comparison of experiences of the different environments in which the students work. The online discussion also enables the teacher to see the level of understanding the students attain, and to provide additional guidance on how to improve their level of understanding of the topic. This could include some guidance on strategies for learning the content materials through application, and on how to make the best use of the online discussions. It is recommended in the teacher's guide that teachers use the online discussion as an assessable activity.

The course materials are designed to enable the problem tasks and the online discussions to complement each other to provide an engaging and challenging learning environment.

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Application and Evaluation

The first trial application of the program at the Institute of Land and Food Resources, The University of Melbourne, ran into some difficulties that highlight some of the issues associated with online delivery. The difficulties were firstly that many of the students were at the beginning stages of computer literacy and did not know how to handle some of the computer processes, such as downloading files and saving them to a directory where they could be found again and used. Secondly, the equipment in the local college learning space was not up to the standard required, and many of the students did not have the type of equipment at home that was needed to run the program through the TAFEVC. These problems seemed to compound each other and students became very frustrated trying to work online through the TAFEVC. Another huge disincentive for students to work online was encountered when for long periods of time access to TAFEVC became temporarily unavailable. This meant that students could not access TAFEVC when they wanted to, when they were ready to learn. They were thus being denied what is one of the primary aims of online learning – accessibility. A questionnaire was completed by most of the students in the trial after the subject was completed. Table 2 summarises student feedback on technical aspects of the trial implementation. (Note that in the following table 'SA' refers to 'strongly agree', 'A' refers to 'agree', 'NS refers to 'not sure/does not apply', 'D' refers to 'disagree' and 'SD' refers to 'strongly disagree').

	SA	A	NS	D	SD
1. The way to use the online technologies was made clear to me from the beginning.		4		2	1
2. I experienced difficulties in gaining access to the online subject materials.	2	2		2	1
3. After the initial problems of connection were overcome, access to the online materials was consistent and effective.	1	2	1	2	1
4. The multimedia-based technology helped me to learn effectively.	1	3		3	

Table 2: Student feedback on technical issues

In order to overcome the problems associated with access students were provided with the program on CD. This provided students with good access to the course material, however it did not give the students the opportunity to download and submit files and also to become part of and contribute to online discussions. In a sense we were providing the students with an electronic book without the interactions we believed to be so important at the start. Student feedback on matters of interaction with other students, summarised in Table 3, indicates the limitations associated with the lack of the online discussion capability.

	SA	A	NS	D	SD
10. I had to consider several different points of view in the group discussion of the problem tasks.		3		2	2
11. I worked closely with other students on the group learning tasks.			1	4	2
12. I learned a lot from the other students while working on the group learning tasks.		1		3	3

Table 3: Student feedback on interaction with other students

The students generally felt very comfortable about the online course materials. They learnt the menu system very quickly and became adept at working through the course materials. They enjoyed the interactivity of some parts of the program and also the links to useful soil web-sites, which were provided online. The PBL approach also helped focus students on the problem at hand. Here was a problem, which they could realistically expect to encounter if they were pursuing a career in horticulture, which needed to be addressed. A number of students were so enamoured with the

PBL approach that they actually asked what became of Andrew and Julie (the two growers profiled in Soils online) and their venture. Other students commented that Andrew and Julie provided an experiential framework, which made it much easier for them to follow in completing their own soil investigations. Student feedback on the problem-based learning tasks is summarised in Table 4.

	SA	A	NS	D	SD
5. The best way to approach learning was clearly explained in the online subject materials.		4	2	1	
6. The problem situation had some features that were familiar to me.		5	1	1	
7. I found the problem situations challenging.		6	1		
8. The problem tasks enabled me to develop my existing knowledge of the topic.		5	2		
9. I gained a greater understanding of how to meet farmers' needs from working on the problem-solving tasks.		5	1	1	

Table 4: Student feedback on the problem scenarios

Conclusions

The PBL approach provided an effective basis for the design of this courseware. Using this approach, the starting point for design was a definition of the skills the student would need on completion of the course. These were defined as abilities that the student would need in the work environment rather than knowledge of a topic. The PBL approach encourages designers and teachers to focus on authentic, real-world, tasks that, as in the work environment, are not always clearly defined with one specific solution. An example in this program is the task of conducting a soil analysis on the student's own property. The skills in addition to content knowledge that the students learn relate to investigation, communication, IT, and dealing with ambiguity among others – all valuable skills in any professional environment.

The online resources enable teachers to use PBL effectively, even in a distance-learning environment. The difficulties of using the more open-ended learning tasks that are typical of PBL include management of the process and providing all of the resources that the students need to explore the dimensions of the task. The online materials provide access to all content materials at the click of a mouse, access to other sources such as the Victorian Resources Online and CSIRO sites, and a means of managing the process through the online discussions and regular assessment tasks. Students can explore the content for problem-solving and use the online discussions to share ideas and information. The realistic nature of the problem tasks is intended to provide a stimulating and motivating environment for learning.

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